GENERAL INFORMATION REPORT 53

Building a sustainable futur

Homes for an autonomous communi

Living in equilibrium with the environment will be a key issue the design of homes and communities of the third millenni

Case studies:
Sherwood Energy Village and the urban autonomous house in Nottinghamshire.

GENERAL INFORMATION REPORT 53

NEWARK & SHERWOOD

Newark & Sherwood Energy Agency

BEST PRACTICE PROGRAMME

ENERGY EFFICIENCY

BEST PRACTICE

FOREWORD

The concept of sustainable development is attracting increasing interest from central and local government, from designers and planners, and from those specifying and developing individual houses and complete communities.

This Report reviews some of the issues involved and offers a number of design solutions for further discussion. It is based on studies by Brenda and Robert Vale who were commissioned by BRECSU, on behalf of the Department of the Environment, Transport and the Regions (DETR) to propose:

- specifications for zero CO_2 emissions, zero heating and autonomous dwellings
- a design guide for sustainable housing development based on Sherwood Energy Village.

The purpose of the studies was to begin to define a standard for autonomous communities and for the houses within them.

It should be noted that the building standards discussed in this Report are substantially higher than those required by current Building Regulations and have not been widely replicated in practice even among practitioners working in this field. They should, therefore, not be interpreted as firm recommendations. Rather they should be treated as a basis for advancing the debate on how to respond to the need for sustainability in future housing developments.

CONTENTS

1	INTRODUCTION	4
2	PLANNING FOR SUSTAINABLE DEVELOPMENT	6
	Local planning	6
	Site layout	6
	Transport	7
	Density	8
	Green space	8
	Case study – Sherwood Energy Village, Nottinghamshire	9
3	SUSTAINABLE HOMES	12
	Life in a sustainable community	12
	Zero CO_2, zero heating and autonomous standards	13
	Building fabric considerations	16
	Theoretical energy use	18
	Potential health benefits	19
	Case study – The autonomous house, Southwell, Nottinghamshire	21
4	CONCLUSION	22
	REFERENCES	23
	FURTHER READING	24

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1 INTRODUCTION

SUSTAINABILITY

The UK Government's four broad objectives for sustainable development are: social progress which meets the needs of everyone; effective protection of the environment; prudent use of natural resources; high and stable levels of economic growth and employment.

At a global level, sustainable development may mean, among other things, the prudent use of fossil fuels which are, with present use, not sustainable. At the household level, it must imply the ability to afford a reasonable standard of living, and to do this without adversely affecting the future.

A DEFINITION

Sustainable development is defined as 'development that meets the needs of the present without compromising the ability of those in the future to meet their own needs'[1].

INTRODUCTION

Sustainable development involves finding ways to combine social, economic and environmental goals. It will involve action from all sectors of society, from Government to business, communities and individuals. In order to build consensus on the best ways forward for sustainable development, the Government recently conducted a wide-ranging public consultation exercise on revision of the 1994 UK Sustainable Development Strategy. A revised sustainable development strategy is due around the end of 1998, which will contain indicators and targets for sustainable development in the UK.

This publication represents one vision of the factors likely to contribute to sustainability at a community scale, with ideas on the layout, density and transport considerations in settlement design. No doubt, other views on sustainable design will be proposed in the future. Detailed design issues have also been considered in this respect and the three standards relating to house design and specification – zero CO_2, zero heating and autonomous – are based on theoretical studies of energy consumption in houses. To achieve such standards in practice will inevitably require homeowners to play their part by using energy and material resources more efficiently.

Communities in the third millennium will have to live in equilibrium with their surroundings. But this need not mean abandoning our traditional homes and communities in favour of the futuristic, high-tech living of popular science fiction.

Several initiatives already encourage us all to use energy more efficiently, and current Building Regulations lay down the energy-efficient fabric measures which must be incorporated in new-build properties. However, achieving the desired equilibrium for the future is likely to mean a comprehensive re-think of building and site design, coupled with a gradual shift to more sustainable life-styles.

A desirable feature of a sustainable community is that, on balance, it should not contribute any of the greenhouse gas carbon dioxide (CO_2) to the atmosphere (net zero CO_2 emissions).

Such a community might feature:

- local generation of energy for local use by wind, solar and biomass
- interconnection of work, housing, community and leisure facilities
- opportunities for local employment as a result of the local provision of services
- homes and gardens compatible with sustainable lifestyles.

These features have the potential to create stable communities with increasing community self-reliance.

Homes for a sustainable community are likely to be of superinsulated, high thermal mass, airtight construction; and building materials should be non-toxic and of low ‘embodied energy’. Space should be found for water collection, sewage treatment, waste recycling and energy generation.

Thus the importance of an integrated design approach cannot be overstated. The issues of house size, construction, energy use, water collection and waste treatment interact with one another in ways that may be in harmony or in conflict.

This Report sets out the basic requirements for a sustainable community, highlighting issues which will affect planning and construction decisions, and presents design strategies for dwellings that will be compatible with current and future lifestyles.

community

2 PLANNING FOR SUSTAINABLE DEVELOPMENT

Careful site planning and provision of facilities, and a well-thought-out transport policy must accompany forward-looking home design to achieve the autonomous requirements of a sustainable community.

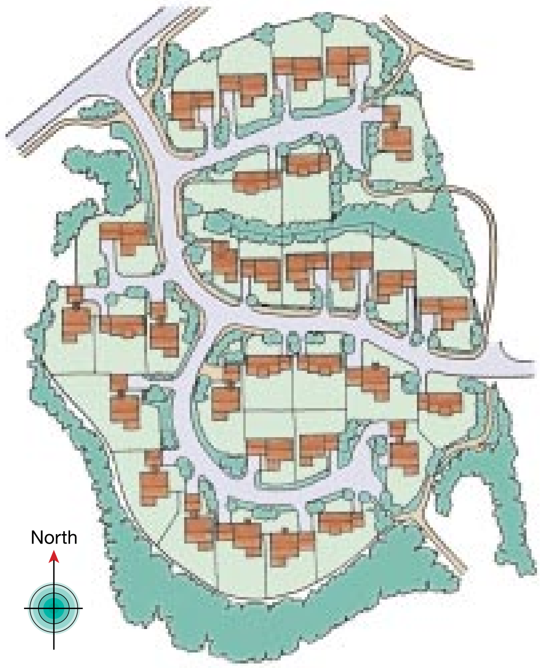
LOCAL PLANNING

The plan of a sustainable community needs to take account of factors that are not usually considered in the planning of settlements, as well as the normal considerations. Such unusual aspects will include the orientation of the development to maximise the ability to collect energy both actively and passively. This suggests plots that allow wide south-facing façades. There may be a difference between plots on opposite sides of an access road. The layout will entail leaving appropriate sites for wind turbines on hilltops. It will require the integration of dwellings, workplaces and shops, and the design of reasonably level and sheltered roads that favour walking and cycling. It will also mean the integration of food production at differing scales throughout the community.

SITE LAYOUT

Passive solar gains and sunlight are welcome in the winter in any house. As far as possible the most glazed sides of all buildings should be oriented towards the south, or up to 30° either side of south. To minimise heating demand, it is beneficial to reduce the area of north-, east- and west-facing glazing. However, windows should be large enough to provide adequate daylighting. It is probably worth concentrating the glazing on the south façade, but it is not worth making these south-facing windows much larger than normal, for reasons of both cost and heat losses at night. If buildings do not incorporate thermal mass to absorb solar heat gains it will be necessary to take care that excessive gains are not encouraged.

South-facing elements should be unshaded as far as possible in the winter, certainly between 9.00 am and 3.00 pm. To achieve this there should be no obstruction to the south within an altitude angle of 10°. This applies with even greater emphasis to properties incorporating photovoltaic arrays – the array can lose most of its output if even a small area is in shade. Such arrays also show a



An example of a careful but informal layout consisting of passive solar houses with a southerly orientation[2]

considerable fall off in performance as their temperature rises, so they may be best accommodated on free-standing structures rather than roofs, to give a cooling airflow over the rear of the panels. These free-standing arrays may be used as additional water collection surfaces.

Planting is a good way of increasing the year-round usability of outdoor spaces such as gardens and terraces by providing windbreaks, but the use of planting to reduce airflow through houses is not relevant when airtight superinsulated construction methods are to be used. Care must be taken that planting does not obscure sunlight and begin to shade solar collecting areas as it matures.

There is a conflict between the need for low-density development and the desire to minimise roads, but in many areas of a sustainable community roads might be made quite simple, and of porous construction to avoid the need for conventional surface water drainage. The design of roads with smooth paving only for cyclists and pedestrians could help to emphasise the message of reduced car use.

PLANNING FOR SUSTAINABLE DEVELOPMENT

TRANSPORT

Movement is a vital part of any settlement, but how that movement is achieved has effects on the environment. Transport was responsible for 20% of UK CO_2 emissions in 1993; the current figure is 30% and it is probably rising[3].

A sustainable community should be planned to encourage movement on foot or cycle, and to discourage the use of cars powered by fossil fuels. Development in the community should be sited as close as possible to public transport routes, with a maximum walking distance of 300 metres as a goal. Electric buses, as used in Oxford, might be a possibility for local travel, and any public transport provision needs to be integrated with existing systems. (However, it should be noted that at normal occupancy a suburban train uses more energy per passenger kilometre than a small car.)

The most fuel-efficient mode of powered transport is an electric bicycle. Table 1 shows transport energy demands in kWh per passenger kilometre. **Electric vehicles in general offer the possibility of zero-emissions transport if the electricity is supplied from renewable sources.** They can be produced economically in relatively small numbers, particularly when made from composite materials.

Transport	kWh per passenger kilometre
Electric bicycle	0.01 (100%)
Electric car (two-seater)	0.06 (50%)
Express coach (diesel)	0.08 (65%)
Diesel InterCity 125 train	0.22 (50%)
Electric InterCity 225 train	0.29 (50%)
1.8 litre diesel car	0.33 (35%)
1.1 litre petrol car	0.39 (35%)
Suburban train	0.47 (22%)
2.5 litre diesel car	0.50 (35%)
2.9 litre petrol car	0.78 (35%)
Internal air flights	0.97 (65%)

Notes:
The percentages in brackets are typical occupancies. (Adapted from data from the Royal Commission on Environment and Pollution, 1994, given in Bell M, Lowe R and Roberts P 'Energy Efficiency in Housing' Avebury, Aldershot, 1996, p67; plus electric car data from Dunkley B 'British Designers keep it Simple' pp17-19; Electrotechnology April/May 1994; and measurements of UK-made 'Citibike' electric bicycle in use, made by Robert Vale in 1996/1997)

Table 1 Transport energy demands in kWh per passenger kilometre

Several car manufacturers are beginning to produce electric vehicles, giving the possibility of renewably powered transport

PLANNING FOR SUSTAINABLE DEVELOPMENT

DENSITY

The density of the proposed settlement has an important effect on its degree of energy self-sufficiency. Recent proposals for denser developments, by concentrating on traffic considerations, ignore the effects of other energy uses and the possibilities for their reduction. For example, a four-person household living in a standard modern house will create CO_2 emissions of about 4.2 tonnes (1.15 tonnes of carbon) per year from their use of the house (heating, hot water, cooking, lights and appliances) (see table 2, page 12). A car averaging 20 000 km per year with a fuel consumption of 8.5 litres per 100 km (corresponding to 33.4 mpg) uses 1700 litres of petrol per year. This represents about 16 000 kWh, with a CO_2 emission of 4.4 tonnes[4]. However, the CO_2 emission attributable to the growing, processing, packaging and transport of the food they eat is closer to 8.0 tonnes per year[5].

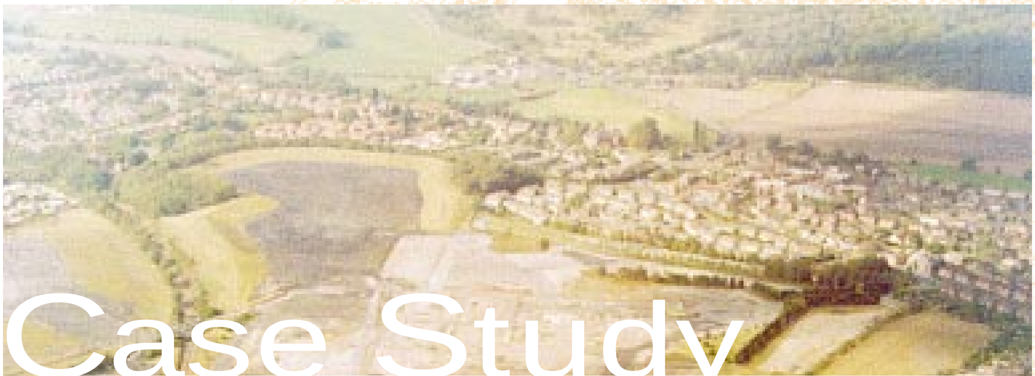
Food production in the garden is not really possible in a high-density settlement, and the old Garden City density of 12 houses per acre (30 per hectare) may be more appropriate for a sustainable community. This will require careful planning to keep travel distances to a minimum within the settlement, but it will make the on-site generation of electricity and the collection of water much easier than in a dense settlement.

GREEN SPACE

Open space, in addition to that normally provided, might include areas of allotments so that all residents do not have to have home vegetable gardens. Areas could also be provided to encourage birds and wildlife, through planting with appropriate native plants. In this way, increased use could be made of existing landscape features and of areas that are unsuitable, through orientation or location, for residential or other development. Footpaths and cycle paths could pass through such areas, which should be linked to form linear wildlife corridors through the community, using and reinforcing existing hedgerows and waterways.

The deliberate integration of the natural environment with that of the community will be an important aspect of the community's visual impact and ambience. Footpaths should be attractive to residents, and could provide a network of routes through the community, with small open spaces, both play areas and quiet places, at frequent intervals along them, between the larger wildlife areas. These public open spaces should be planted with fruit trees as a demonstration both of the possibilities of community-scale food production, but also as a way of making the village visually different from a conventional settlement. Lawns and mown grass areas should as far as possible be avoided in the landscaping, as these are very low in wildlife value.

PLANNING FOR SUSTAINABLE DEVELOPMENT



Case Study

SHERWOOD ENERGY VILLAGE, NOTTINGHAMSHIRE

Sherwood Energy Village is based in the existing villages of Ollerton and Boughton in north Nottinghamshire. The closure of Ollerton colliery and others in the Nottinghamshire coalfield in the early 1990s removed from the village, as from many others, its principal source of employment. In response, community regeneration activists, including the Ollerton and District Economic Forum, have designed Sherwood Energy Village, an initiative that adds ‘sustainability’ to ‘local economic regeneration’.

The Village, which is a cooperatively owned Environment Enterprise Park, has set out to demonstrate a ‘zero CO_2 autonomous industrial community’. Ownership of the 50 hectares of buildable land was secured in 1996 by Sherwood Environmental Village Ltd, an industrial provident society for the benefit of the community, which is currently seeking joint venture partners to secure the estimated £175 million needed to develop Sherwood Energy Village. Ten percent of the land – approximately 9 hectares – has provisionally been allocated for housing.

Sherwood Energy Village will be designed to attract visitors, giving added employment both in general tourism and in the servicing of conferences and similar gatherings. What makes Sherwood Energy Village different from existing and proposed ‘eco-tourism’ developments, indeed its unique feature, is that it is not a display but a complete working community.

The homes in the village will have no emissions, car use will be reduced, and the need to concentrate on minimising the emissions attributable to food will require a radical approach to land use. Thus there will be a trade-off between housing densities and localisation of food procurement in partnership with the existing nearby allotment associations. Transport, leisure and work must also be catered for in innovative ways. And, while heat and power may be obtained from local renewable sources, house design must also ensure that energy efficiency standards are as high as possible.

PLANNING FOR SUSTAINABLE DEVELOPMENT

PROPOSED MASTERPLAN PHASE 1

PLANNING FOR SUSTAINABLE DEVELOPMENT

Planners and Architects: BENOY

3 SUSTAINABLE HOMES

The domestic sector is responsible for 30% of UK carbon emissions, mainly due to the CO_2 emitted as a by-product of power generation and burning fossil fuels. Table 2 shows the CO_2 emissions (and equivalent carbon emissions) associated with a 'typical' three-bedroom semi-detached house built to 1995 Building Regulations standards.

	kg CO_2	kg C
Space heating	1506	411
Hot water	864	236
Cooking	125	34
Pump and fans	96	26
Lights and appliances	1650	450
Total	**4241**	**1157**

Table 2 CO_2 and equivalent carbon emissions for a typical house built to 1995 Building Regulations standards

Creating a sustainable community will, to a large extent, depend on the standard of energy efficiency of the homes within the community.

Housing associations, local authorities and independent construction companies are already building homes that exceed the 1995 Building Regulations, and use the Government's Standard Assessment Procedure (SAP) to measure performance. However, achieving energy efficiency of the level required for a sustainable community requires a radical re-think of materials, methods and design.

A pair of superinsulated houses for North Sheffield Housing Association

LIFE IN A SUSTAINABLE COMMUNITY

A sustainable community offers its residents a way of life that should be more comfortable, more self-reliant and more in harmony with the natural world than the norm. It will do this without compromising living standards, and without greatly increasing capital costs.

However, there is no doubt that life in a sustainable community will be different from life on a conventional new housing estate. Residents will have different responsibilities to themselves and their families, such as managing their water supplies. They will have different responsibilities to the wider community, such as reducing their car use. In parallel with this they will gain benefits in very practical terms, such as very low costs for heat, light and power, water and sewage treatment, as well as the less tangible benefits of knowing that, by their actions, they are helping to reduce their environmental impact.

Materials choice, water supply and sewage treatment, and fuel procurement need to be considered, as well as more conventional issues such as thermal performance, and mechanical and electrical servicing requirement. Homes may be evaluated using the BREDEM-based SAP. Homes for sustainable communities are designed to have the lowest possible impact on the environment, as measured using BRE's BREEAM[6] for new housing and its subsequent replacement, the Environmental Standard[7].

With this in mind, three new standards have been developed which present a way forward. Each standard represents a design strategy that can be used to create a home which is 'traditional' in appearance but radical in use. The standards offer increasing challenges and opportunities to the designer, builder and householder, in that each standard contains the attributes of the one below it, then adds a further improvement in the level of performance.

ZERO CO_2, ZERO HEATING AND AUTONOMOUS STANDARDS

1 A ***zero CO_2*** house creates no net emissions of CO_2 on an annual basis. This means that it must obtain its heat and power from renewable energy. It may do this by buying electricity on a 'green tariff' from a company generating renewable energy. If the house makes use of any non-renewable energy sources, it must have its own renewable energy system of sufficient capacity such that, during any year, it can export enough renewable energy to compensate for the CO_2 emissions associated with other imported energy.

2 A ***zero heating*** house normally obtains all its space heating needs from its occupants and their activities, combined with solar and other casual heat gains. The definition of performance will be based on the calculated performance of the house when analysed using BREDEM-8 or BREDEM-12 developed by BRE. The zero heating calculation assumes that the house is occupied by its designated number of residents (based on provided bed-spaces), that low-energy appliances are used, and that all lights are compact fluorescent lamps (CFLs). These latter requirements are to avoid the use of high appliance and lighting loads to boost available heat gains. A 'nominal zero heating' house may have a heating system installed to cope with the higher temperatures or heat demands associated with, for example, babies and young children, elderly or disabled occupants, under-occupancy, illness, and periods of extreme weather.

3 An ***autonomous*** house must meet the zero CO_2 and zero heating standards defined above, but it must achieve this by the use of on-site renewable energy generation, which may be a stand-alone system or grid-linked. It must not use any mains services apart from electricity and, if it is linked to the electricity grid, in any year it must export sufficient renewably generated electricity from its own system to balance its intake from the grid. In addition, it must provide its entire water supply and treatment services from the resources it can collect from its site, without the need for mains connections, and it must process its own waste water and sewage within the confines of its site. No waste water or sewage discharges of any kind must leave the curtilage of the site, including surface water run-off. (In this context, 'the site' may be taken as the boundary of the housing estate to allow communal autonomous solutions to be proposed.)

All three standards are designed to include 'low embodied energy' construction, where 'embodied energy' is all the energy used to produce and transport the physical fabric of the building. In addition, they will be powered by renewable energy, so that they provide a net zero CO_2 emission standard during operation. It is expected that the forthcoming 'green tariff' offered by electricity companies will allow consumers to purchase, direct from the grid, energy produced from renewable resources.

Homes built to any of the three standards will offer low-pollution living conditions, as well as emitting lower levels of pollutants to the atmosphere. Non-toxic materials offering minimum emissions of, for example, formaldehyde, volatile organic compounds and solvent vapours will be used in houses. Because electricity is used for cooking there will be fewer pollutants (carbon monoxide, oxides of nitrogen) in the house caused by combustion.

A well-controlled ventilation system (either a passive stack system with humidity control intakes and extracts, or a mechanical system with heat recovery) will ensure that the indoor air quality remains healthy. This means that great care must be taken in the detailing and construction of joints between elements and components to avoid unwanted air infiltration; and the completed house must be pressure tested to ensure the required performance is achieved[8].

The hot water cylinder will be superinsulated to minimise heat loss; while the demand for hot water will be reduced because such houses will have aerating taps for use in basins and showers, in preference to baths (maximum flow rate 6 litres per minute).

The compact design of the hot water system will lead to greater efficiency, and all hot water pipework will be fully lagged. In addition, appliances in all dwellings will need to be the most energy and water efficient listed in the EU rating scheme, and the lighting will use CFLs throughout.

Kitchen fittings of emissions-free softwoods are cost-effective for social housing

SUSTAINABLE HOMES

The biggest difference between traditional homes and houses built to one of the three standards is likely to lie in the degree of commitment to environmental performance shown by the occupants of the various house types. To desire to live in a zero CO_2 house implies a degree of understanding of environmental concerns. This understanding may lead to a more energy-efficient lifestyle with fewer, or smaller appliances (a larder fridge, rather than a fridge-freezer); more efficient ways of operating them (using cold-water detergents in the washing machine); more care over consumption

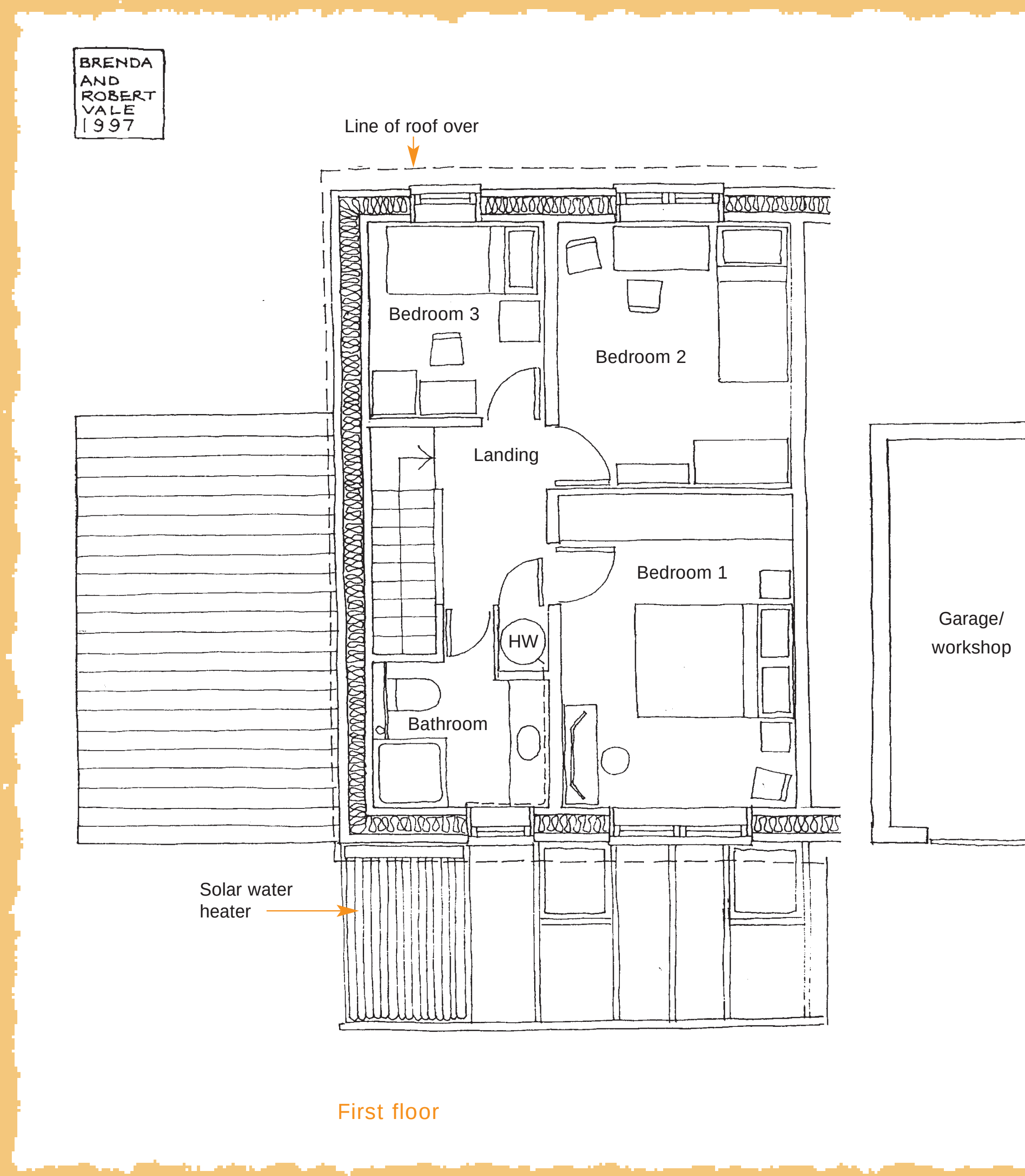
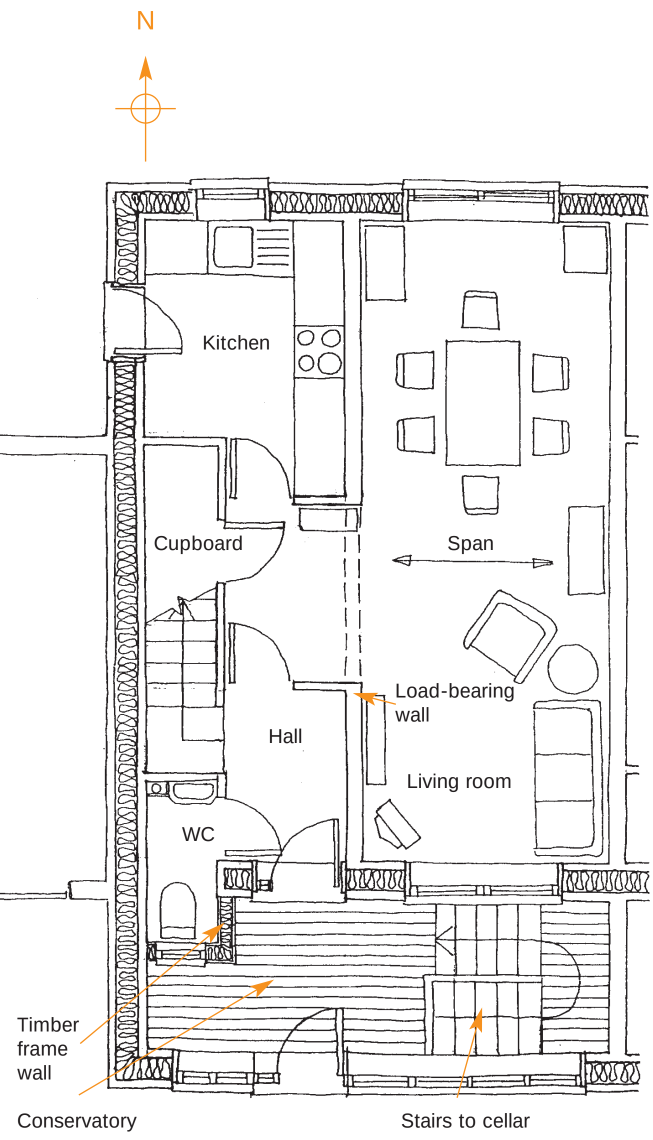


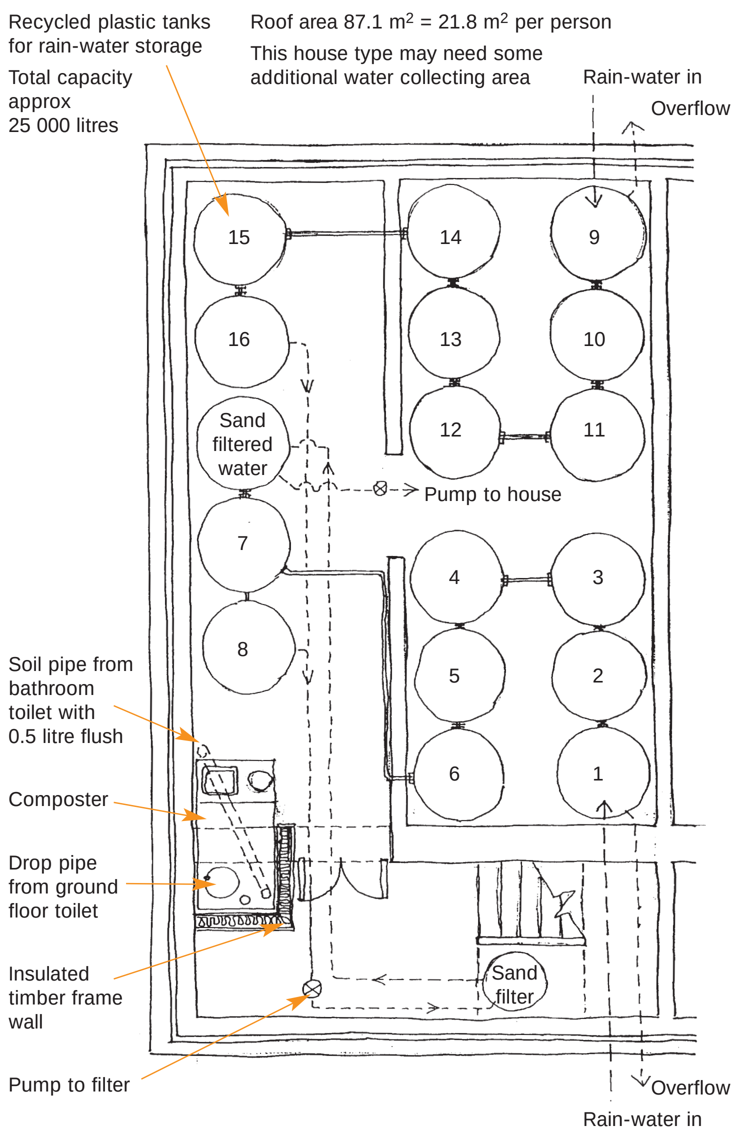
Figure 1 Floor plans for a typical autonomous house based on BRECSU standard house type

generally (four-minute showers); more cycling and walking rather than car use; and so on.

The three standards are, in theory, applicable to all sizes of dwelling – from a single bedroom, to four or five bedrooms. This section focuses on the way in which any of the three specifications can be applied to a ‘typical’ three-bedroom semi-detached house – a very common house type across the UK. The basic plans are shown in figure 1.



Ground floor



Cellar plan for autonomous servicing

sustainable living

SUSTAINABLE HOMES

The typical three-bedroom semi-detached house, as currently built, is of masonry cavity wall construction, with a concrete slab ground floor, a timber first floor, and a trussed rafter roof. Windows are sealed double-glazed units in softwood frames. Table 3 shows the specification for the 'typical' house, and compares it to some of the features required for houses built to the standards defined on page 13.

BUILDING FABRIC CONSIDERATIONS

Any house could become a zero CO_2 house by choosing to be all-electric, and then buying the electricity on a 'green tariff'. This provides a route into the sustainability standards for the occupants of existing homes who wish to reduce their environmental impact. However, to reduce energy demand, a new-build zero CO_2 house will have higher levels of thermal insulation than a house built to the current Building Regulations (although lower than the other two standards proposed). The insulation levels for a zero CO_2 house can be incorporated into conventional house designs, although ensuring that built performance is as specified would require close site supervision.

	Heating	Controls	Hot water	Ventilation
Typical three-bedroom semi	Central heating from gas-fired, wall-mounted, fan-assisted, low-thermal-capacity boiler	Programmer, room thermostat, cylinder thermostat and thermostatic radiator valves	160-litre cylinder with 38 mm foam insulation	Extract fans to kitchen and bathroom
Zero CO_2	Back-up system of wall-mounted electric panel heaters in all rooms, with electric 'feature fire' in living/dining-room. Green tariff	Thermostats and timers built into each panel heater, and thermostat on living-room fire	Equivalent of 150 mm zero ozone depletion foam insulation to cylinder	Pressure test to 3 air changes per hour (ach) at 50 Pascal (Pa); humidity-controlled passive stack system
Zero heating	As above	As above	180-litre cylinder with 150 mm insulation all round, including the base, all pipe connections to cylinder; thermostat and timer-controlled immersion heater; showers and spray taps	Whole-house system, pressure tested to 1 ach at 50 Pa; whole-house mechanical ventilation system with heat recovery (efficiency at least 60%), plus 8000 mm^2 adjustable trickle vents on all windows
Autonomous	Combination of solar and passive gains, with back-up as for zero heating house	As above	As for zero heating, but power for heating water is generated by a solar heating system and/or heat pump	Fan-assisted stack ventilation to cellar, rest as per zero heating standard

Table 3 Taking the specification for the 'typical' house as a base, each of the three standards adds a cumulative improvement towards the autonomous requirement

Table 4 shows the levels of insulation required by the 1995 Building Regulations compared to levels required for the zero CO_2 and zero heating standards.

The fabric U-values for the zero CO_2 standard result in a 60% reduction in space heating demand (calculated). This means that a very simple heating system can be used and, combining this standard with renewable energy bought on a 'green tariff', the capital costs of extra fabric insulation are met by what would have been spent on a typical central heating system. Cost studies and practical experience[9] have shown that houses to these standards can be built for a capital cost the same as, or lower than, conventional houses.

The zero heating house uses standard building materials and components to achieve its performance. It has a heating system installed for 'emergency' use only. The external walls are also of masonry cavity wall construction, like the typical house, but with a greatly increased cavity width to allow 250 mm thick resin-bonded glassfibre insulation, and an inner leaf of dense concrete block for thermal mass. The wall ties are made of glass-reinforced plastic to reduce thermal bridging. The ground floor is a power-floated concrete slab on 300 mm thick expanded polystyrene insulation, with foundations detailed to minimise thermal bridging. The first floor uses a concrete beam-and-block construction to give improved airtightness (compared to building in timber joist ends to a masonry wall) and additional thermal mass. The roof has timber trusses, modified to allow 500 mm thick cellulose fibre insulation without thermal bridging at the eaves. The sprayed-in cellulose fibre provides airtightness for the ceiling. Windows have softwood frames, but use triple glazing with low-emissivity coatings and gas filling to reduce heat loss, and they have rubber gaskets for airtightness. They are mounted in plywood linings to avoid the thermal bridging associated with conventional cavity closing techniques. External doors are of insulated sandwich construction fitted in draught-tight frames. Within the shell of the house the plan is modified slightly to provide the necessary supporting walls for the concrete first floor, and to allow more of the internal walls to be made of dense concrete blockwork to add thermal mass.

	Fabric U-values (W/m²K)		
	1995 Building Regulations (SAP over 60)	Zero CO_2	Zero heating
Roof Flat roofs and sloping parts of the room in the roof	0.25 0.35	0.10 (300 mm cellulose fibre)	0.08 (500 mm cellulose fibre)
Ground floors	0.45	0.20 (150 mm expanded polystyrene under entire slab)	0.10 (300 mm expanded polystyrene)
Exposed floors	0.45	0.20 (as ground floor)	0.10 (as ground floor)
Exposed walls	0.45	0.20 (150 mm full-filled cavity)*	0.14 (250 mm full-filled cavity)*
Semi-exposed walls	0.6	0.20 (as exposed walls)	0.14 (as exposed walls)
Windows, doors and rooflights	3.3 (overall value for whole element)	2.20 (overall value for whole element)[10]	1.70 (overall value for whole element)[11]

*Suggested constructions with thermal mass (see examples in [9]). Appropriateness of full-filled cavity dependent on exposure to wind-driven rain. Other types of construction are not precluded but would require further analysis.

Table 4 U-values for the 1995 Building Regulations standard, compared with those for the zero CO_2 and zero heating standards

The bathroom is positioned above the ground floor WC to simplify pipework.

The additional costs of the zero heating standard when compared with an all-electric typical three-bedroom semi-detached house can be offset from the summation of:

- savings on the capital cost of the heating system
- lower operating costs for servicing and fuel.

The fabric of the autonomous standard is based on the zero heating specification (see table 4), but self-sufficiency in terms of on-site renewable energy generation, water supply and sewage treatment makes direct comparisons more difficult.

SUSTAINABLE HOMES

Cost studies of an autonomous version of the zero heating house described above indicate an additional cost of £13 000 for a photovoltaic system and a hot-water heat pump. However, as technology and market demand improve, costs for these renewable energy investments for the domestic sector are expected to fall. For water and sewerage a capital expenditure of £4500 will be needed in addition to the summation of savings as a result of:

- savings to mains utility infrastructure and connection charges
- additional funding financed from water and sewerage bill savings.

Energy use (kWh) (electricity unless stated)			
	Typical	**Zero CO_2**	**Zero heating**
Space heating*	7926 (gas)	3172	240 (calculated by EA Technology for an open site in Manchester region)
Hot water*	4548 (gas)	2319	1660****
Pump and fans	175	–	200 (mechanical ventilation)
Cooking**	656 (gas)	330	330
Lights and appliances***	3000	2700	2100
Total	**16 305**	**8521**	**4530**

Notes
* Calculated from the SAP method, unless stated otherwise
** Average cooking figures from data given in [12]
*** Data from [13]
**** Hot water figure could be reduced to 690 kWh per year using a heat pump, based on SAP data for heat pump at 240% efficiency

Table 5 Theoretical energy use of a typical UK house built to 1995 Building Regulations standard compared with houses built to the zero CO_2 and zero heating standards

THEORETICAL ENERGY USE

As built, the typical three-bedroom semi-detached house will use roughly 16 300 kWh of energy per year, and an annual CO_2 emission of about 4.2 tonnes (see table 2). Table 5 compares this base case energy requirement with the needs of the two lower ‘standards’.

Energy use for a new build zero CO_2 house is calculated to be approximately 8500 kWh per year. Energy use for space heating and hot water will be lower than the typical house because of increased insulation and more efficient services; and energy use for cooking will be lower because, unlike its typical comparator, the zero CO_2 house will have an energy-efficient electric oven, hob and grill. Energy is also saved by the reliance on passive ventilation and more energy-efficient lighting and appliances.

As expected, the zero heating house takes these standards further, having heating for ‘emergency’ use only, and utilising the 40 W mechanical ventilation and heat recovery (MVHR) system which is assumed to run continuously over a seven-month heating season. A 30% reduction in water use and distribution losses is expected, compared with the typical house (achieved by the measures listed in table 3).

In addition, there is an expected 30% reduction in the use of lighting and appliances by using the most energy-efficient equipment on the market, and installing compact fluorescent lighting. This results in CO_2 emissions which equate to about 2.5 tonnes (0.68 tonnes of carbon) per year from non-renewable sources. This value will vary according to the way the occupants respond to the house and their use of energy. It could also be reduced to about 2.0 tonnes (0.55 tonnes of carbon) if a heat pump or solar collector was used for hot-water provision. For example, the energy used for heating water could be reduced to 690 kWh per year using a heat pump with a coefficiency of performance (COP) of 2.4 would give an overall demand of 3560 kWh.

SUSTAINABLE HOMES

POTENTIAL HEALTH BENEFITS

There are likely to be considerable benefits to local health service providers responsible for sustainable homes and communities, because homes will be affordable to heat and offer an improved indoor environment. The provision of 'affordable warmth' has been a major problem for people on low incomes. Direct links have been identified between low indoor temperatures and increased blood pressure. The design of homes that can be kept warm with little or no heating should provide health benefits by enabling the occupants to keep warm without it costing much money. There are also likely to be health benefits as a result of omitting materials that can affect indoor air quality, and by avoiding the use of fitted carpets which provide a home for the house dust mite, which is strongly linked with asthma. The growth of mites will be further reduced by the use of controlled ventilation in houses. The provision of space for home vegetable growing will offer both exercise and fresh produce for the householder. On a wider scale, the focus of the village on walking and cycling rather than car use will encourage exercise, while reducing air pollution from car emissions.

The autonomous standard

The autonomous house shows considerably more differences from the typical house than the other two standards, largely because of the need to provide a water supply and sewage treatment. In line with the concept of direct conversion of the typical house plan, these services are accommodated in a cellar below the house. In addition, the house must meet its energy needs from its site, so there are attempts to reduce its demand compared to that of the other versions. This is helped by the inclusion of a south-facing conservatory, which also provides the access to the cellar. The conservatory acts as a source of solar heated air and helps reduce the demand for back-up space heating.

The cellar contains the compost chamber for the waterless composting toilet, which converts the wastes to garden fertiliser, and is odourless in operation. The chamber is ventilated through a fan-assisted stack rising up through the house. The use of a waterless toilet makes possible the collection of sufficient water from the roof of the house and garage to meet reasonable household needs, even in an area of low rainfall such as eastern England, but it requires the cooperation of the residents to make careful use of the water. It is also important that appliances such as the washing machine are as water-efficient as possible, and that they are used carefully – only with a full load, for example.

The cellar also provides a space for the water storage tanks that hold rainwater collected from the roof. The water is passed through a sand filter before use in the house, and is further treated at the kitchen tap by a ceramic filter candle.

The autonomous standard is the version that has the most need of informed and enthusiastic occupants. Occupants may also have to accept lower internal temperatures for short periods in winter. Not only are there simple but unfamiliar technologies to be managed, such as the sewage composter and the water system, but the house has to supply all its energy from on-site generation, albeit with a connection to the grid for two-way exchange of power. This means that the number and type of appliances must be carefully controlled if the cost of the generating system is to be kept to a reasonable level. The principal impact will be on hot water production, which will have to be by means of a solar heating system and/or a heat pump, in order to reduce the electricity demand for back-up heating to a level that can be supplied by a relatively modest renewable energy system.

SUSTAINABLE HOMES

	Energy use (kWh)	Comment
Space heating	0	Assumes that no heating will be used – simulations by EA Technology suggest a living-room minimum temperature of 16.5˚C*
Hot water	700	Assumes either 8 m^2 solar panels, or a heat pump, plus demand management by the occupants
Pump and fan	100	Assumes a 12 V DC MVHR unit drawing 20 W continuously over the heating season
Cooking	300	Assumes a 10% saving over the average figure for electric cooking used in table 5
Lights and appliances	1000	Based on demand in the Southwell Autonomous House, which used 1230 kWh per year for lights, appliance and cooking (reduced demand assumed through appliance choice and careful management by the occupants)
Total	**2100**	

*Assumes standard and continuous occupancy[14]. Based on open aspect, no significant shading. Some heating required to dry out house after construction. Internal temperature could fall below this minimum at certain times of the year for other occupancy patterns.

Table 6 Theoretical minimum energy use in the autonomous standard

A house built to the autonomous standard is likely to use about 2100 kWh per year, and will need a 2.8 kW photovoltaic array to satisfy this demand (see table 6). Similarly, water use in a conventional UK household is 145-180 litres per head per day, whereas in an autonomous house it is 34 litres per head per day[15] Even allowing for the water used for toilet flushing, consumption in an autonomous house is less than a third that of a conventional household.

These descriptions of apparently 'lower' standards of consumption compared to conventional housing might suggest that autonomous householders are in some way disadvantaged, but they receive benefits not available to the resident of a typical house.

The first of these is the minimal running costs of the house – no water or sewerage charges and no, or low, fuel bills. (This last aspect would require the local electricity company introducing 'net billing' with electricity supplied to the grid being used to offset the cost of electricity taken from the grid, the annual cost will be nil if the tariffs for 'in' and 'out' are equal.) The other benefits relate to the satisfaction of living with less impact on the global environment, which to many may form a considerable attraction.

The autonomous standard house will be more expensive to build than a conventional dwelling. However, on a reasonable scale of development, the costs of providing autonomous services to a group of houses would be partly offset by the avoided costs of sewers, water pipes, gas mains and surface water drainage required for a new estate.

Case Study

THE AUTONOMOUS HOUSE, SOUTHWELL, NOTTINGHAMSHIRE

In 1993 the first 'autonomous' house in the UK was built in the Newark and Sherwood area. The house is designed to be environmentally friendly and self-sufficient in water and energy, and to treat its own wastes on site, as well as offering a healthier indoor environment to its residents.

The house comprises a 2.5 storey detached residence above an unheated cellar. The total floor area of the various spaces is approximately:

House	169 m^2 on 3 levels
Porch	7 m^2
Cellar	66 m^2
Lower conservatory	28 m^2
Upper conservatory	20 m^2
Total	**290 m^2**

The house has no mains services except electricity and telephone.

Architects: Brenda and Robert Vale

The selection of materials for building the house resulted from careful assessment of their embodied energy. For example, the house foundations rest on demolition rubble from old brick buildings, rather than gravel.

To supply the total energy needs of a 'conserving' household, this house uses a 2.2 kW photovoltaic array, providing between 750 kWh and 850 kWh per kW per year, whereas to meet the electricity consumption of an average UK household would require a 4.0 kW array, at considerably greater initial cost.

The total contract sum for the project was just under £155 000. This gives a cost of some £540 per m^2, if one includes the areas of the conservatory, porch and cellar in the calculation, and £920 per m^2 if one takes the 'house' alone. A typical UK house will cost approximately £450-500 per m^2.

4 CONCLUSION

Credit: North Notts Newspapers

Aerial photograph of the Sherwood Energy Village site

The zero CO_2 and zero heating house standards can readily be applied to conventional housing; the autonomous standard, on the other hand, offers considerably greater challenges to builders and occupants alike. While individual autonomous houses have been built[15] the greatest benefit will be achieved by creating communities based on such criteria.

With the domestic sector responsible for 30% of UK carbon emissions, the impact of sustainable housing would, in time, be considerable. If houses were built to the autonomous standard there would be additional benefits in terms of reduced developmental pressures on existing infrastructure and treatment systems.

At the same time as offering benefits to the environment, the houses described in this Report would provide householders with lower bills, and a protection from future price increases in servicing costs, thereby promoting a greater sense of security.

The benefits from the building of such houses and communities based on similar principles, operate at three levels; there are benefits to the planet (reduced CO_2 emissions); to the UK (reduced pollution, infrastructure and health costs); and to the householder (lower bills and improved indoor environment).

REFERENCES

[1] World Commission on Environment and Development. 'Our Common Future' p43. Oxford University Press, Oxford, 1987

[2] Willow Park, Chorley, UK. An example of passive solar design.

[3] 1993 figure from DETR 'Indicators of Sustainable Development for The United Kingdom' p80. DETR, London, 1996

[4] Calculated on the basis of 9.6 kWh per litre of petrol and a CO_2 emission of 0.27 kg CO_2/kWh; data from 'Non-Domestic Building Energy Fact File'. DETR, London, 1998

[5] Calculated for the UN FAO dietary recommendations for a family of four from Fisher P and Bender A 'The Value of Food' p22. Oxford University Press, 1970; plus food production energy overhead for UK agricultural and food processing system from Leach G 'Energy and Food production' p8 International Institute for Environment and Development, London, 1975

[6] Prior J, Raw G and Charlesworth J. BREEAM/New Homes: An Environmental Assessment for New Homes. BRE, Garston, 1991

[7] Prior J and Bartlett P. Environmental Standard: Homes for a Greener World. BRE, Garston, 1995

[8] A pressure test result of one air change per hour at 50 Pa is recommended for houses with mechanical ventilation and heat recovery systems. See Bell M, Lowe R and Roberts P. 'Energy Efficiency in Housing' p28. Avebury, Aldershot, 1996

[9] See, for example, '45-47 Cresswell Road' in General Information Report 39 (GIR 39). 'Review of ultra-low-energy homes. Ten UK profiles in detail' pp 17-21. DETR, London, 1996

[10] Overall U-value for double-glazed window with low-emissivity glass and argon filling in a wooden frame; given in the SAP method. The Building Regulations 1995; Approved Document L, 'Conservation of Fuel and Power'; Appendix G. DETR and the Welsh Office. HMSO, London, 1995

[11] Overall U-value for triple-glazed window with two low-emissivity panes and krypton gas filling calculated by EA Technology, allowing for thermal bridging at head, cill and reveals

[12] Wilson K. 'An Examination of some Energy Consumption Aspects of Domestic Cooking Practices' in 'Proceedings of XV International Home Economics and Consumer Studies Research Conference' Part 1, pp72-87. Manchester Metropolitan University, Sept 1995

[13] From Boardman B et al. 'DECADE: Domestic Equipment and Carbon Dioxide Emissions'. Second Year Report Energy and Environmental programme, Environmental Change Unit. University of Oxford, 1995

[14] Anderson BR, Chapman PF, Cutland NG, Dickson CM and Shorrock LD. BREDEM-12 Model description. Garston, BRE, 1996

[15] Data from measurements at the Autonomous House, Southwell, Notts, 1993-96

FURTHER READING

DETR ENERGY EFFICIENCY BEST PRACTICE PROGRAMME DOCUMENTS

The following Best Practice programme publications are available from BRECSU Enquiries Bureau. Contact details are given below.

General Information Reports

38 Review of ultra-low-energy homes. A series of UK and overseas profiles

39 Review of ultra-low-energy homes. Ten UK profiles in detail

Good Practice Case Study

340 Environmentally sensitive housing. Dallow Road, Luton

FURTHER READING

BRE

CRC Ltd, 151 Roseberry Avenue, London EC1R 4QX
Tel: 0171 505 6622. Fax: 0171 505 6606.

- BR278 Environmental Standard: homes for a greener world (1995)
- BR351 The green guide to specification. An environmental profiling system for building materials and components (1998)

Energy Efficiency Best Practice in Housing

Tel: 0845 120 7799
www.est.org.uk/bestpractice

Energy Efficiency Best Practice in Housing is managed by the Energy Saving Trust on behalf of the Government. The technical information was produced by BRE.